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Potential of using groceries in disasters/pandemics management: case of Al Ain City, UAE

M. M. Yagoub[a], Tareefa AlSumaiti[a], Naeema Alhosani[a], Marwan Elmubarak[a], Othmane Kortbi[b], Yacob T. Tesfaldet[a], Mohamed Al Namani[a] and Sarah R. Aldhanhani[a]

[a]Department of Geography and Urban Sustainability, College of Humanities and Social Sciences, UAE University, Al Ain, United Arab Emirates; [b]Department of Analytics in the Digital Era, College of Business and Economics, UAE University, Al Ain, United Arab Emirates

ABSTRACT

Scopus database between 2000 and 2023 showed that while groceries are vital in disaster/pandemic management, their roles have not been adequately addressed in the literature. In this study, we argued that privately owned groceries can complement large food storage facilities and provide effective and sustainable Public–Private Partnerships-PPP for disaster/pandemic management. We supported our argument with surveys of 254 customers and 100 grocery tenants, as well as a spatial analysis utilizing Geographic Information Systems (GIS). The results indicated that 62% of customers and 89% of grocery tenants agreed that grocery sales increased during COVID-19. Furthermore, 75% of customers agreed that groceries are vital during disaster/pandemic, and 81.8% of grocery tenants agreed that their current infrastructure allows their stores to become emergency food depots. Through GIS analysis, we found that groceries are clustered around population centers, and 69% of customers have groceries within a 5–10-minute walking distance. Our results demonstrated that groceries can be crucial in disaster management. The study aligns with the Sendai Framework for Disaster Risk Reduction 2015–2030 and UN-SDG goals 11 and 17. The findings could be utilized by organizations working in the field of disaster/pandemic management. The research fills a gap in the literature and offers new insights into the potential of using privately owned groceries in disaster/pandemic management. It highlights the need for further consideration of these important community resources.

IMPACT STATEMENT

There are many lessons learned from COVID-19 pandemic. For example, the need for decentralization of food stores and cooperation between public and private sectors (Public–Private Partnerships-PPP). This study provides insights on how privately owned groceries can complement large food storage facilities and provide sustainable PPP. Feedback from grocery tenants and customers showed that groceries can be crucial in disaster management. The grocery sector could bring innovative solutions to food distribution during a disaster/pandemic. Integration of Geographic Information Systems (GIS) is found crucial in supporting surveys. PPP can save time, save cost, improve efficiency, and bring various benefits to stakeholders involve in disaster management.

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1. Introduction

The emergence of COVID-19 prompted cultural, social, and economic systems to adjust their routines, structures, and processes (Magd et al., 2022; Rokooei et al., 2022). The food industry as one of these systems, has experienced interruptions, and this led to a significant reduction in the food supply chain (Hobbs, 2020). The food distribution network made plans and strategies to cope with the pandemic. To

CONTACT M. M. Yagoub myagoub@uaeu.ac.ae Department of Geography and Urban Sustainability, College of Humanities and Social Sciences, UAE University, Al Ain, United Arab Emirates.

evaluate the lessons learned from this experience there is a need to understand perception of customers and those who worked in the food retail sector.

Distribution of food during a disaster/pandemic is one of the important and challenging tasks. Experience around the world showed difficulty in ensuring equitable distribution of emergency food resources to communities following a disaster (Singleton et al., 2022). This creates a need for cooperation between public and private sectors for establishing emergency food distribution sites. The call for cooperation (public–private partnerships-PPP) is encapsulated in the Sendai Framework for Disaster Risk Reduction 2015–2030 (United Nations Office for Disaster Risk Reduction (UNDRR), 2015). A PPP is defined as collaboration between public and private sectors in working towards common objectives through a mutually agreed upon division of labor and by committing resources and sharing the risks as well as the benefits (Buse & Walt, 2000).

One of the lessons learned from COVID-19 is the need to increase PPP so the best available resources may be put into action to reduce disaster/pandemic risks and improve the life and well-being of humans. According to several case studies, numerous international policies account for sharing of responsibilities between private and public sectors during disasters (Burnside-Lawry & Carvalho, 2015; Busch & Givens, 2013; Jerolleman & Kiefer, 2015; Nkombi & Wentink, 2022). For instance, Meduri (2016) discussed how the participation of 45 different stakeholders helped in better management of the cyclone Hudhud that hit the state of Andhra Pradesh, India in October 2014. American retail company Walmart's food support provided to disaster victims of Hurricane Katrina in 2005, for instance, represents a public–private partnership (Abou-Bakr, 2013; Van der Berg, 2015). In United Arab Emirates (UAE), the federal law of the National Emergency, Crisis, and Disasters Management Authority (NCEMA) stipulates that the government may utilize the potential and expertise of the public and private sectors to provide necessary assistance during emergencies, crises, and disasters (National Emergency, Crisis and Disasters Management Authority (NCEMA), 2011). Since the enactment of the NCEMA, the Authority has received the cooperation of various organizations such as the Emirates Red Crescent and telecommunications companies.

Cooperation between public and private sectors (stakeholders) can provide sustainable approaches for disaster management, improve social infrastructure, efficiently manage resources, employ multiple stakeholders' skills, provide quick response, and enhance community resilience (Auerswald et al., 2009; Auzzir et al., 2014; Eyerkaufer et al., 2016; Stewart et al., 2009). Therefore, public disaster management authorities and the private sector can cooperate in securing emergency food supply. Efforts could be made to minimize the challenges of PPP such as conflicting objectives, data sharing, accountability, long-term commitment, imbalance in resources contribution, and in implementing disaster management policies in an integrated and transparent way (Busch & Givens, 2013; Khan & Rahman, 2007).

Earlier studies related to groceries were limited in scope and most of them were focused on customer satisfaction or application of Geographic Information System (GIS), whereas this study combined both and added perception of groceries' owners. Therefore, the research provides a holistic framework about the role of groceries in disaster/pandemic management. Perdana et al. (2022) conducted a systematic literature review on food supply chain management in disasters and found that research into the policy assessment and stakeholder engagement is lacking. Our study tries to fill this literature gap by focusing on stakeholder engagement coupled with Geographic Information System (GIS).

The objectives of this study are as follows:

- Assess perception of customers to the role of groceries during COVID-19. This objective focuses on how the public get use of the groceries during COVID-19 lockdown and whether groceries are accessible to them and meet their food needs.
- Assess perception of grocery store tenants in using the stores as food emergency depots. The objective is to get feedback from tenants regarding their willingness to use their groceries as food emergency depots and check the size of grocery, storage area, and condition of the grocery structure. The feedback could be used to support public–private partnerships-PPP.
- Assess geographical distribution of grocery stores. Survey may not give the actual geographical distribution of grocery stores. Therefore, GIS was used to check the proximity of groceries to residential areas.
- Assess vulnerability of grocery stores to natural hazards. Flash flood is the main natural hazard in Al Ain city. The intention is to check if some groceries are located in areas vulnerable to flood and consequently could not be used as food emergency depots.

We hypothesized the followings:

1. Sales of grocery stores increased during COVID-19, reflecting the importance of the stores during pandemics.
2. Current infrastructure of grocery stores allows these stores to become food emergency depots.
3. Grocery stores are randomly distributed (dispersed).
4. Most customers have grocery stores within walking distance.

The novelty of the research lies in its contribution to the bodies of knowledge on disaster management and response, specifically in food security and distribution. The study also offers a framework for involving various stakeholders to form public-private partnerships (PPP). Additionally, the research provides a guide for the formulation and setting of policies and regulations on the distribution, size, and building of groceries relative to population densities and potential disaster risks. This is significant as it contributes to improving sustainability and resilience capacities, which are high-priority strategic goals in numerous countries around the world.

The remainder of the paper reviews previous work related to the research, describes the methodology and data processing, results, discussion, and concludes with some recommendations.

2. Literature

In several countries, emergency food is often addressed by building large long-term storage facilities. Facilities may be built in sites that may be affected by disasters, disrupting supply chains. During the Nepal earthquake of 2015, the Nepalese meat industry became highly affected when thousands of meat producers were locally centralized, leading to considerable supply chain disruption and meat products becoming unavailable to consumers (Reddy et al., 2016). Similarly, in 2005, the slow crisis response to Hurricane Katrina in the USA was attributable to insufficient food distribution centers near affected zones (Manners-Bell, 2014). A study assessed emergency food distribution efforts in New Orleans, LA following Hurricane Ida's landfall on August 29, 2021 pointed to considering factors beyond geographic access of site locations including operations and resource offerings such as quantity of food (Singleton et al., 2022). Lessons from these disasters can help countries prevent food disruptions. Thus, evaluating food disruption threats and risks is critical for improving urban area emergency preparedness and response efforts.

Emergency food security should begin at the community level. Typically, communities would become better prepared in anticipation of, during, or after pandemic/disaster if communities are made aware of where emergency food is stored and how it will be delivered, especially in terms of existing transportation networks (UK Government, 2016). For example, in the USA, preparedness plans often begin with a template assessing community-level local food storage capacities (University of Alaska Fairbanks, 2015). Bringing essential services closer to residential neighborhoods is more effective and improves community resilience during disasters (Schiller, 1986; Vega et al., 2015). Cities could build neighborhood- and community-level local storage capacities by creating an inventory of grocery stores and identifying coverage areas and facilitating the inclusion of these facilities in emergency preparedness plans. Previous studies related to grocery stores focused on various aspects such as accessibility (USDA Economic Research Service, 2014), residents' shopping habits (Cannuscio et al., 2013), and retail environment (Martin et al., 2014). However, studies on how grocery stores can serve as food distribution centers during disaster/pandemic are scarce (Hitomu et al., 2020).

Spatial distribution is key in determining how grocery stores can help during disasters/pandemics. Spatial distribution is a function of the interactions of numerous factors including population density, facility type and location, residential arrangements, accessibility, and urban traffic conditions (Cromley, 2019; Luan et al., 2015; Shi et al., 2015). Spatial distribution of grocery stores could provide guidance to the government and partners in targeting food distribution in the initial phases of a disaster. Evidence from previous disasters indicated inequality in distribution of groceries (Biju, 2014) and economically and socially disadvantaged populations are more likely to experience the detrimental effects of natural

disasters (Singleton et al., 2022). A study by Esmalian et al. (2022) assessed access to grocery stores for socially vulnerable populations during different phases of the 2017 Hurricane Harvey in Harris County, Texas. They used various access indicators such as redundancy, rapidity, and proximity and high-resolution data from Streetlight (points-of-interest (POI)), visit data from SafeGraph, sociodemographic information, and Flood data. They found that areas with higher income have better access to grocery stores (travel longer even the area has lower number of stores). Their study falls within the scope of accessibility and did not address the perception of customers and grocery owners to use the groceries as disaster depots. Therefore, understanding public perception of owners/tenants about the role of stores during a disasters/pandemics are essential. During COVID-19, online food services increased in number (Alice, 2020). However, during disasters, online services/order fulfillment are vulnerable to losses in internet connection and electricity, or blockage of roads may become an issue (Wisetjindawat et al., 2015). Therefore, grocery stores within walking distance will become viable alternatives.

Published articles related to the role of groceries during pandemic or disaster were checked using Scopus database. The Scopus database was chosen because of the availability to the authors. The search was conducted on February 2023, with a search query (grocery AND pandemic OR disaster OR accessibility OR distribution OR hygiene OR 'Online shopping') on abstract, title, and keywords. Further the search was restricted to peer reviewed articles published in journal in English language. The result obtained 1415 documents published between 2000 and 2023. After performing keyword cooccurrences on the 1415 articles the most ten occurred terms were retained (Table 1).

The keywords proportion was further grouped into six themes namely: pandemic (54%), online shopping (25%), accessibility and distribution (14%), GIS (4%), hygiene (2%), and customer satisfaction (1%). Majority of the papers related to COVID-19 addressed supply chain disruptions (Sukhwani et al., 2020), food access (O'Hara & Toussaint, 2021), and online shopping (Hao et al., 2020). However, there are only five papers that addressed the role of groceries during the pandemic (Braut et al., 2022; Fernandes-Jesus et al., 2021; Goossensen et al., 2023; Jacobson et al., 2022; Sukhwani et al., 2020). This indicates there is a gap in the literature related to the role of groceries in disaster/pandemic. In this study, we gather responses from both grocery tenants and customers to understand the role of groceries during the pandemic/disaster. Moreover, we utilized Geographic Information System (GIS) for spatial analysis. GIS is instrumental in all phases of comprehensive emergency management including prediction, identification, mitigation, preparedness, response, and recovery (Balaji et al., 2002; Chande et al., 2020; Dong et al., 2020; Federal Emergency Management Agency (FEMA), 1995; Laefer et al., 2006). GIS can integrate diverse data (Roy et al., 2000), saving time and costs, facilitating better visualization, presenting a holistic view, and ensuring a safer population. However, GIS analysis results are inadequate for providing better decisions. Therefore, integrating public perception is essential.

To consider grocery stores in emergency preparedness and planning for food supply, assessing vulnerability because of natural hazards is necessary. It is vital to have a good understanding of the geography of the disaster hit area for deciding the right way of action (Meduri, 2016). Rain-induced flash floods are among the common natural hazards causing property damage in the UAE (Alsenaani, 2013; Dhanhani et al., 2010; Yagoub et al., 2020; Yagoub & Al Yammahi, 2022). Therefore, vulnerability of groceries to flash flood was assessed.

In this study, we utilize Al Ain city as a study area because of data availability. The retail market continues to expand as the city population increases (Yagoub, 2006; Yagoub et al., 2015). The study focuses on

Table 1. Top ten keyword occurrences on research related to groceries.

Keyword	Occurrences	%
COVID-19	289	44.6
Online shopping	119	18.4
Accessibility	43	6.6
Nutrition	33	5.1
Food Access	31	4.8
Retail	31	4.8
Grocery	30	4.6
Consumer behavior	28	4.3
Food availability	26	4.0
Food environment	18	2.8
Total	648	100

groceries because of their proximity (walking distance) to residential areas. Public–private partnership (PPP) is evident in groceries. For example, in 2016, Al Ain city led a rehabilitation program related to activities of groceries. Various government departments participated in this program (Zawya, 2016).

3. Method

The research methodology employed in this study was based on a survey and spatial analysis tools (GIS). We used questionnaires to gather data about the role of groceries from customers and grocery tenants (Appendix A). We obtained ethical approval for the survey from the Social Sciences Ethics Committee at the Research office, UAE University, on 24 August 2022. Two questionnaires were prepared, one for customers and the other for grocery tenants. We obtained feedback from different stakeholders (public–private) to cross-check the role of groceries. The objective of the study was explained to the participants, and they were assured that all information will be confidential and used in summary form for research purposes only and they can withdraw from the questionnaire at any time.

Questionnaires for customers consisted of four main sections, and each section presents certain questions (Appendix A). These sections include accessibility, size, and condition of structure of groceries, food needed by residents, role of groceries during COVID-19, and demography. Questionnaires were then prepared in Google Forms and distributed online during September and October 2022. Reminders were sent via e-mail and social media. Approximately 254 responses were obtained, which are considered sufficient based on the exploratory nature of the study and difficulty of obtaining responses. Nkombi & Wentink (2022) used a 42-respondent sample to assess the prevailing opinions and beliefs relative to public participation in disaster risk reduction.

The second questionnaire was distributed to grocery tenants. In this study we surveyed 100 grocery tenants that are geographically distributed throughout the study area. The sample size is deemed within the normal range for grocery chains surveys. Jacobson et al. (2022) surveyed 53 grocery chains to assess supply chain disruption and increase demand during the COVID-19 pandemic in Canada. Similarly, Ansari (2020) surveyed 60 valid samples for Original Equipment Manufacturers (OEM) in Oman. The groceries functions were considered like OEM because they provide services.

Questions for grocery tenants include whether sales increased during COVID-19, most common foods type needed (e.g. rice, lentils, flour, dry grains, and beans), average amount/stock of canned food, size of grocery and storage area, condition of the grocery structure, and whether grocery infrastructure allows stores to become emergency food depots. These questions will provide an overview about the current state of groceries, needed food items by community, and average amount. This study assessed the relationship between area of grocery (independent variable) and amount/stock of rice/canned food, size of storage area, and whether size has any effect on answers of tenants 'Does the current infrastructure of your grocery allow it to become an emergency food depot?' We then distributed the questionnaire to groceries.

Descriptive statistics and correlation among dependent and independent variables were performed. We assessed the relationship between size of groceries (independent variable) and average rice stock, amount of canned food, storage areas, and whether the grocery could be used as emergency food depots (dependent variables). Since most variables are ordinal scale variables, we used the Spearman's correlation test based on the ranks of data rather than the values of the variables. Moreover, the Likert type questionnaire was summarized into five themes. The mean value was computed from all the responses and labeled as very high (≥4.21), high (3.41–4.20), moderate (2.60–3.40), low (1.81–2.60), and very low (≤1.80) (Tesfaldet et al., 2022). The survey responses were analyzed using the Statistical Package for the Social Sciences (SPSS) software (SPSS version 28.0.0, IBM, Chicago, USA).

Spatial analysis tools (GIS) were used to assess the spatial distribution of groceries using average nearest neighbor index, point density, kernel density, and hot spot analysis. We used the average nearest neighbor index to check whether the grocery distribution is dispersed or clustered. Nearest neighbor analysis utilizes the distance between groceries to determine if the pattern is random, regular, or clustered (Chang, 2014; Clark & Evans, 1954). Our null hypothesis assumes that groceries are randomly distributed (dispersed). If the index is less than 1, this pattern exhibits clustering; conversely, if index is greater than 1, this trend is toward dispersion or competition (Environmental Systems Research Institute (ESRI), 2017).

Point and kernel densities were used to calculate grocery density. Point density computes the density of point features around each output raster cell (Environmental Systems Research Institute (ESRI), 2017). Neighborhoods were defined around each raster cell center, and number of points falling within the neighborhood were added and divided by the area of the neighborhood (Silverman, 1986). Kernel density estimates the probability density function of a random variable using distance between points (Getis & Ord, 1992; Silverman, 1986). In point density, neighborhoods that calculate the density of the groceries around each output cell were specified, while kernel density spreads the known quantity of the groceries for each point out from the point location. The search radius (bandwidth) for the kernel density was set to 1000 meters (walking distance) and cell size is 100 meters.

Density indicates where clusters in data exist, but not if clusters are statistically significant. To determine significance, we used a hot spot analysis (Getis & Ord, 1992). We considered groceries as incident data representing objects where the focus is on presence or absence (incident intensity) and whether they are clustered spatially. Data were aggregated by joining the groceries to 'District' file and counting the number of groceries in each district. We used the 'count' field in hot spot analysis (Getis-Ord Gi*) (Spatial Statistics). The z-score (standard deviations) and p-value (statistical probability) were calculated, where higher z-scores (above 1.96 and below −1.96) indicate high spatial clustering, and smaller p-values ($p \leq 0.05$) indicate statistically significant clustering.

We assessed correlation between population and number of groceries using correlation coefficient, Gini index, concentration index, and accessibility. To determine correlation between population and number of groceries, we calculated the number of groceries in each district using spatial join. Each district was then given a summary of the numeric attributes of groceries. The attribute table includes each district population and number of groceries were exported to Excel. We employed ordinary least squares regression to analyze the relationship between population (independent variable- explanatory variable) and number of groceries (dependent variable) and determine their statistical significance ($p \leq 0.05$). A strong positive correlation implies that groceries are decentralized (equally distributed).

We used the Gini index to assess the distribution of groceries among population (equality). Originally, the Gini coefficient/index/ratio is used in economics to assess the distribution of income/wealth and quantify inequality in other applications (Cromley, 2019; Gini, 1936; Norheim, 2010; Yitzhaki, 1979; Zheng et al., 2013). The Gini coefficient may comprise number ranging from 0 (equality-balanced) to 1 or 100% (inequality) that measures the degree of inequality in a set of data and is calculated based on Lorenz curve. We generated a Lorenz curve representing distribution of groceries. A diagonal line represents an equal distribution of groceries, and the higher the deviations of the Lorenz curve from this line, the greater the inequality. We calculated the Lorenz curve and concentration index based on the procedure used by Yagoub (2006).

Another element of analysis was to assess accessibility of groceries. Accessibility was assessed by calculating the distances between population centers and facility locations (Cromley, 2019; Moore & Diez Roux, 2006). This study assumed that during disasters, use any means of transportation is more difficult. Therefore, buffers of 1 and 1.5 kilometers were established around the groceries and used to measure access (walking distance), and areas beyond these distances are considered to have inadequate access (Ver Ploeg et al., 2015). We then calculated the total area covered by all buffers. This area was divided by the total built-up area of districts that have population densities greater than 10 persons per square kilometer (threshold for sparse population). Finally, we used the result to calculate the percentage of population who have groceries within 1 and 1.5 kilometers.

In the city, flash floods were the main natural hazard (Yagoub & Al Yammahi, 2022). Flash floods occur because of heavy rainfall occurring in short time frames, despite annual average rainfall being low (40 mm). Since the study area is small, rainfall is considered constant, and the vulnerability of groceries to flash floods was assessed by identifying groceries at low elevation and in proximity to valleys. Elevation of groceries was extracted from Digital Elevation Model (DEM) via extracting by attribute. We used the 'near' tool in ArcGIS software to calculate distances between the groceries and the valley layer. We reclassified distances and elevations to a common risk index of one (low probability) to five (high probability) (Marin-Ferrer et al., 2017). We produced output hazard maps as average of scales and summarized as low, medium, and high.

GIS data were obtained from various sources. Grocery locations were obtained from Google Earth and the Al Ain Maps website (Ain Maps, 2021). Population at the district level was obtained from Al Ain Town

Planning Department. Finally, we obtained the digital elevation model (DEM) from the United States Geological Survey (USGS) Earth Explorer website (USGS, 2020).

4. Results

4.1. Result of the customer survey

Most respondents are females (75.6%), at a university (83.1%), single (76.8%), and with low income (47.6%) (Table 2), which is expected owing to most survey participants being from the United Arab Emirates University, and 78% of the students at the university (14,387 students) being females (UAE University, 2022). Previous study by Bender et al. (2022) about food system resilience showed that the majority of participants were female since food management responsibilities continue to be disproportionately borne by women.

Approximately 69% of respondents have groceries within 5–10 minutes walking from where they live. However, of the respondents, 50% order through delivery, 40% drive, and 10% walk.

Most respondents (63.4%) prefer rice as the nonperishable foods. Chicken and milk suggest equal demand (35%). Rice and canned food needed by respondents per month ranged between 5 and 15 kilograms (Table 3).

Most respondents (62%, score = 3.75) agreed that their purchase from groceries increased during COVID-19, and 68% agreed that grocery staff apply health/hygienic protocols (Table 4). Respondents (68%) strongly suggested that staff at groceries must have certificates or short courses in health/hygiene

Table 2. Demographic characteristics of respondents (number of respondents = 254).

Variable	Variable	Frequency	Percent
Gender	Male	62	24.4
	Female	192	75.6
Education	School	11	4.3
	University	211	83.1
	Graduate (Master or PhD)	32	12.6
Marital status	Married	59	23.2
	Single	195	76.8
Employment status	Employed	57	22.4
	Unemployed	197	77.6
Age	Less than 18 years old	20	8
	Between 18 and 25 years old	200	78.7
	More than 25 years old	30	11.8
	Missing	4	1.6
Income	Low: Income below AED 10,000 per month	121	47.6
	Medium: Income between AED 10,000 to 20,000 per month	42	16.5
	High: Income greater than AED 20,000 per month	91	35.8

Table 3. Food needs (number of respondents = 254).

Variable		Frequency	Percent
Nonperishable food	Dry grains and beans	39	15.4
	Flour	37	14.6
	Lentils	17	6.7
	Rice	161	63.4
Canned food	Beans	21	8.3
	Chicken	89	35.0
	Fruits	25	9.8
	Milk	89	35.0
	Tuna	30	11.8
Amount of rice needed	Less than 5 kg	68	26.8
	between 5 and 15 kg	130	51.2
	15–20 kg	38	15.0
	More than 20 kg	18	7.1
Amount of canned food	Less than 5 kg	115	45.3
	between 5 and 15 kg	103	40.6
	15–20 kg	25	9.8
	More than 20 kg	11	4.3

Table 4. Perception of the public on the role of groceries during COVID-19.

Opinion statement	Mean	SD	Level
1. Grocery infrastructure	3.19	0.73	Moderate
2. Sales increased during the COVID-19	3.75	1.15	High
3. Grocery staff complied with public health measures	3.93	1.10	High
4. Grocery staff need to be educated on hygiene	4.00	1.11	High
5. Grocery's role is vital during pandemic or disaster	4.21	1.06	Very High

Table 5. Correlation between size of groceries and total monthly sale.

			Size of grocery	Total monthly sale
Spearman's rho	Size	Correlation coefficient	1.000	.602**
		Sig. (2-tailed)	.	<.001
		N	100	100
	Sale	Correlation Coefficient	.602**	1.000
		Sig. (2-tailed)	<.001	.
		N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6. Point pattern analysis using average nearest neighbor.

Observed Mean Distance	317.2660 Meters
Expected Mean Distance	711.4248 Meters
Nearest Neighbor Ratio	0.445959
z-score	−17.024836
p-value	<0.01

protocols (score = 4.00). Moreover, 75% of respondents agreed that groceries can be essential during natural disasters/pandemics. Overall, 68% of customers are satisfied with grocery performance during COVID-19 (score = 4.21). The result empirically demonstrated the importance of groceries in disaster management. Hence, capitalizing on this public–private partnership (PPP) is necessary.

4.2. Result of the groceries' tenants survey

Most grocery tenants (89%) reported that their sales increased during COVID-19; hence, groceries were essential for meeting people's food needs. Of the respondents, 98% rate the structure of their groceries as good (76%) and very good (22%). This agreed with the customers' opinion (86% of respondents) that the structure of groceries is good and very good, respectively. Most (81.8%) groceries' tenants indicated that the current infrastructure allows their stores to become emergency food depots.

Size of groceries (areas) and the average amount/stock of rice they can store are positively correlated (ρ =.487 at Sig. (2-tailed) <.001). We also found a positive moderate correlation at (ρ = 0.369) between size of groceries and amount of canned food. Strong and significantly positive correlations (ρ = 0.698) was found between size of groceries and storage areas. Moreover, positive correlation (ρ = 0.486) was also found between size of groceries and answers the question 'To what extent do you agree with this statement: my current infrastructure allows my store to become emergency food depot?' Large numbers of groceries (68%) have average monthly total sales ranging between 20,000 and 40,000 United Arab Emirates Dirhams (AED). Size of groceries and total sales (ρ = 0.602) are significantly and positively correlated (Table 5). This sale indicates potential losses of groceries in case of disaster/pandemic disruption (business continuity).

On food stock, most groceries (67%) have an average amount of rice less than 50 kilograms each month, and 81% of them have an average amount of canned food less than 70 kilograms. Stock of rice and canned food at groceries is considered small. This is because customers prefer to buy rice and canned food from malls and supermarkets (less price) and not from groceries. Consequently, groceries store small amounts of rice and canned food (lack of demand). However, groceries at the city center and industrial area have large stocks of rice (average 200 kilograms each month) compared to groceries at residential areas (less than 50 kilograms). This may be because a large number of employees and single persons live

in those areas and prefer fulfilling their daily food needs from groceries in their proximity (minimizing transportation cost). Grocery tenants indicated that maximum sales originate from milk (49%), followed by beans (24%), chicken (8%), tuna (7%), and other products. Some grocery tenants expressed their readiness and ability to provide more nonperishable food, such as rice and flour based on demand.

Most groceries (79%) have 2–3 Multi-deck Daily Refrigerated Air-Cooling systems, and this helps them maintain dairy and other food that needs to be saved at specific temperature. Owing to power interruption due to disaster or any other reason, economic loss will be considerable. However, solar energy use could become a backup alternative during disasters, and this needs further assessment in terms of policy formation and equipment specifications.

4.3. GIS results

Using average nearest neighbor index, point density, kernel density, and hot spot analysis, we assessed spatial distribution of groceries. We found average nearest neighbor index/ratio to be to equal 0.45, indicating more clustering than random distribution of groceries. Given a z-score of −17.03 (how far data is from the mean) and p-value of <0.01, the likelihood that this clustered pattern could be of random chance is less than 1% (Table 6). The clustering is attributable to concentration of groceries within populated areas.

Point density varies between 2 and 12 groceries per square kilometer. Output values from kernel density analysis range between zero and 19.5. Surface value is highest at grocery location. This diminishes as distance from grocery increases and becomes zero at the search radius distance from the grocery. Highest density was found in ranges between 8.42 and 19.53. This can be explained by the intensity and density of the mix of uses in some areas which include residential, commercial, and light industrial activities (Figure 1). Mix use makes areas such as industrial ones an active business and consumer transaction activity center. Moreover, it attracts thousands of customers daily, increasing its economic locational advantages, making it highly desirable for a variety of businesses, particularly groceries.

To be as statistically significant as a hot spot, a feature needs to have a high value and be surrounded by other features with high values as well. Two districts, namely, Sanaya and Zakhir have higher z-scores and are statistically significant ($p \leq 0.05$). Table 7 data indicate high spatial clustering of groceries (hot spot) and no significant cold spot.

There is strong positive correlation ($R^2 = 0.5972$) between population and number of groceries, which implies decentralization of groceries (Equation 1). The correlation coefficient coupled with a GIS output

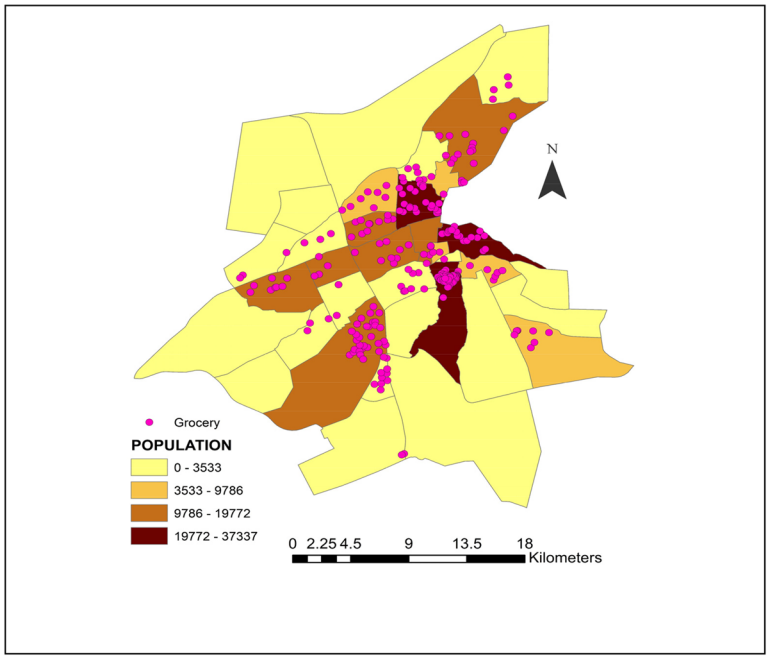

Figure 1. Spatial distribution of groceries in relation to population.

map provide better visualizations on how the relationship varies over space (Figure 1). Moreover, the number of groceries is significant with the number of populations as the calculated p-value equals 9.59448E-06, which is smaller than 0.05 ($p \leq 0.05$).

Gini coefficient was found to be equal to 0.295 (Lorenz curve). This indicates reasonable distribution of groceries among population (Zheng et al., 2013) (Figures 1, 2). The average concentration index of population and groceries (±1) is found to be equal to 0.23, and the smaller value indicates a balanced distribution (decentralized). Regarding accessibility based on distance only, we found that large number of population (62.7%) have groceries within walking distance of one kilometer and 82% are within 1.5 kilometer. Overall, correlation coefficient, Gini index, concentration index, and accessibility indicate reasonable distribution of groceries among population in Al Ain City.

$$Y = 0.0008X + 2.4625 \quad R^2 = 0.5972 \quad \text{Equation 1}$$

where Y = number of groceries and X = number of populations

Field visits revealed other aspects about the distribution of groceries in the city. Based on field visits, numerous groceries are located within proximity to mosques. Spatial locations indicate that 80% of the groceries are located within 200 meters from mosques, and 98% are within 500 meters from mosques. Most groceries (74%) have low flood vulnerability (Table 8, Figure 3). Groceries at low elevation and in proximity of valleys need further assessment related to drainage system and building structure. Output from this study could be used to determine insurance rate based on vulnerability of grocery to flash flood. The value of the grocery is high compared to surrounding residential areas with identical size as it normally contains freezers, food, and other items.

The results support the hypotheses set. This includes:

Hypothesis 1: Sales of groceries increased during COVID-19, reflecting the importance of groceries during pandemics. Most customers (62%) agreed that their purchase from groceries increased during COVID-19. This is

Table 7. Sample of hot spot results.

District	Population	Groceries	GiZScore	GiPValue
1. Sanaya	35086	40	2.862769708	0.004199557
2. Zakhir	13470	34	2.277063701	0.022782422
3. Al Jimi	25284	28	1.691036517	0.090829828
4. Central Business	37337	22	1.105778346	0.268822487
5. Al Mutawaa	2891	1	−0.943546259	0.345401577
6. Al Qattara	5111	2	−0.845793928	0.397667722
7. Al Bateen	446	3	−0.748795273	0.453980615
8. Al Agbiyaa	2536	3	−0.748536768	0.454136462
9. Al Mutaredh	11731	3	−0.748482021	0.454169472
10. Al Masoudi	3533	3	−0.748260109	0.454303287

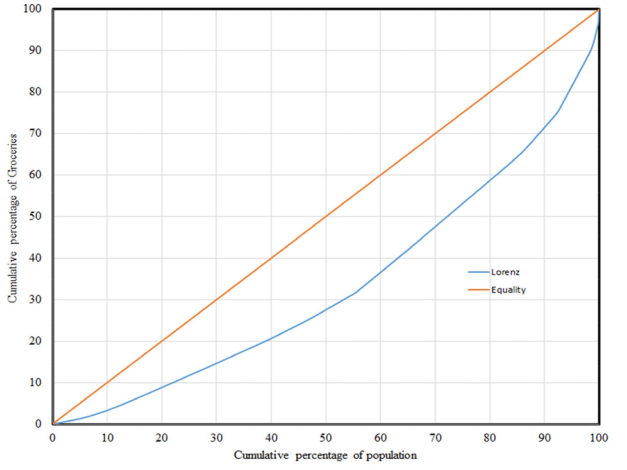

Figure 2. Lorenz curve for number of groceries and population.

confirmed by most grocery tenants (89%) that their sale increased also during the COVID-19. Based on input from customers and grocery tenants the hypothesis is accepted.

Hypothesis 2: Current infrastructure of groceries allows these stores to become emergency food depots. We test the hypothesis by asking our customers to rate the condition of the grocery building/structure near their home. Of our respondents, 85% rated the grocery structure as good (50%) and very good (30%). Conversely, 98% of the grocery tenants rated the structure of their groceries as good (76%) and very good (22%). Based on feedback from customers and grocery tenants, the hypothesis is accepted.

Hypothesis 3: Groceries are randomly distributed (dispersed).

GIS analysis shows that average nearest neighbor index/ratio was found equal 0.45 which indicates more clustering than random distribution of groceries. Given the z-score of −17.03 and p-value of <0.01, there is less than 1% likelihood that this clustered pattern could be of random chance. Based on this analysis, the hypothesis is rejected.

Hypothesis 4: Most customers have groceries within walking distance.

Customer surveys show that 69% of respondents have groceries within 5–10 minutes walking time from their homes. GIS analysis shows that a large number of population (62.7%) have groceries within walking distance of one kilometer and 82% are within 1.5 kilometer. Point density varies between 2–12 groceries per square kilometer. The feedback from customers and GIS analysis imply that the groceries are in proximity of population and can be accessed by walking during a disaster. The hypothesis is accepted.

5. Discussion

Most of the respondents have groceries within 5–10 minutes walking from where they live. Hence, groceries are within walking distance of populations and can be accessed during disasters. People may be ordering their food or driving to groceries because of weather conditions and the COVID-19 pandemic.

Table 8. Vulnerability of groceries to flash flood.

Flood vulnerability	Number of groceries	% Of groceries
Low	192	74.42
Medium	52	20.15
High	14	5.43
	258	100

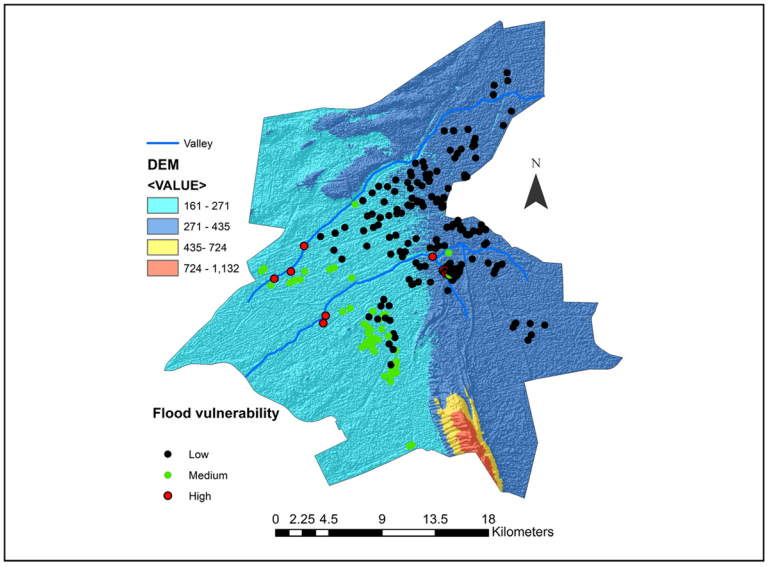

Figure 3. Vulnerability of groceries to flash floods.

Ver Ploeg et al. (2015) found that vehicle use was most common for grocery shopping trips, but less in the lowest income households and in the city center. Another reason could be the fear of contacting COVID-19; hence, people opt driving to groceries (Braut et al., 2022). Therefore, people depend on local groceries where prices are much higher and food quality is generally lower (Cummins et al., 2014; Cummins & Macintyre, 2002; Lee & Lim, 2009).

Regarding the type of food, greater quantities of rice, chicken, and milk are needed during disasters/pandemics. Items needed by customers during COVID-19 that are unavailable in groceries included fruits/vegetables (37% of respondents), chicken (24%), and frozen foods (13%). This gap could be addressed through policy formation, wherein groceries can add items to their lists by considering food with long shelf life. Otherwise, expiration of food before consumption will become a problem for groceries. However, this is a global problem; in Japan, for example, around 30% of 62 local governments disposed stockpiled food owing to expiration and costing around United States Dollar (USD) 2.6 million (Hitomu et al., 2020). In Japan, to circumvent this problem, a rolling stock method, a certain amount of food is stored by replacing old items with new items to maintain the stock (Hitomu et al., 2020).

Most groceries' tenants indicated that the current infrastructure allows their stores to become emergency food depots. This implies that the condition of the grocery structure and tenants' willingness can support disaster management efforts. However, 76% of the groceries have a size and storage area of less than 30 square meters. A similar study conducted by Jacobson et al. (2022) highlighted the key role that grocery retailers have played in ensuring that Canadians have access to food and other essential items during the pandemic. They noted that the industry has faced numerous challenges, including supply chain disruptions, increased demand for certain products, and the need to implement measures to protect workers and customers. Despite these challenges, grocery retailers have managed to remain open and continue to serve their communities. Moreover, most groceries are small and have a small storage area. This limits their capacity to store large quantities of food to support disasters in case of disruption in the distribution network. Moreover, grocery size is an important element. Therefore, we recommended increasing the size of groceries to 50 square meters with similar storage areas to cater for disaster/pandemic needs.

Locations of emerging hot spots are broadly consistent despite variations emerging from the use of different neighborhood distances. Generally, output indicates that distribution of groceries follows the multiple nuclei model and the sector model rather than a concentric zone model (Langenfeld, 2021). This is because the city expanded during the last 30 years in a sectorial fashion. Most groceries are spatially distributed across the city and mostly located in proximity with mosques. This is because most mosques are built by individual donors and are provided the right to build groceries as an incentive wherein groceries that accrued profits are often applied to offset the running costs of these mosques. This constitutes a good partnership and cooperation between the public and the government in increasing access to groceries and is a type of cooperation witnessed worldwide. Pennsylvania Fresh Food Financing Initiative, for instance, utilized funds provided by the state and private organizations to increase groceries and supermarkets in underserved areas across Pennsylvania (Ver Ploeg et al., 2015; The Reinvestment Fund (TRF), 2014). Groceries being located near mosques has an added value in case mosques are used as shelters during a disaster. Another study conducted on a city-level in Taiwan indicates the extent of unequal access to food stores in general. However, at a village-level, the study found that eight villages (which make up 1.8% of the total sample size of 456) showed a high degree of access inequality specifically among older adults. These villages are mainly situated in suburban or downtown areas (Li et al., 2023).

There is general agreement between various stakeholders involved in groceries (customers and tenants) that groceries played an important role during COVID-19. The experience obtained from COVID-19 provides a lesson that will help in policy formation for groceries. The results pinpointed issues that need to be addressed such size of groceries, lack of some types of food, and the necessity of organizing short courses on health/hygienic protocols for the staff at groceries.

5.1. Implications of public–private partnerships (PPP)

Results from this study showed that there is a high potential for public–private partnerships-(PPP) between disaster management authority and the grocery network. The grocery tenants agreed that their

current infrastructure allows their stores to become emergency food depots. Issues related to PPP such as social, theoretical, managerial, and policy implications are important in forming collaboration. The social implications include access to services, equity, affordability, and accountability (transparency). The PPP could bring additional groceries to cover areas that are underserved and hence improve the services and equity. Theoretical implications include market efficiency, transaction cost (resource allocation), and aligning the interests of both disaster management authority and grocery tenants. Managerial implications deal with risk sharing, project management (contract, monitoring), and innovation. The grocery sector could bring innovative solutions to food distribution during a disaster/pandemic. Policy implications deals with regulations, contractual framework (responsibilities and dispute resolution), sustainability (balance risk and return), political considerations (aligning public objectives with private sector interests).

The success of PPP depends on the thoughtful balance between public and private interests, transparency, effective governance structures, and monitoring and evaluation. PPP can bring various benefits, including reduction of the disaster impact, improved service quality, efficiency, increase coverage, innovation, and cost recovery (Johannessen et al., 2013; Zairol et al., 2024). However, PPP also poses challenges that require management to ensure positive outcomes for both the public and private sectors (Busch & Givens, 2013; Kapucu, 2012). Example of these challenges include commitment, participation, coordination, flexibility, trust, self-interests, access to useful resources (knowledge, skills, funding, information, infrastructure), risk management, and conflict resolution (Busch & Givens, 2013; Marana et al., 2018).

6. Conclusion

The study assessed the potential of groceries as food emergency depots during disasters/pandemics. Groceries are considered as an example of public–private partnership (PPP) for disaster management. The assessment is based on perception of the public (customers and grocery tenants) supported with spatial analysis (GIS). Results from the customer and grocery tenant surveys showed higher agreement with the concept of PPP and the role of groceries during COVID-19 provided and evidence.

Various methods were used to assess the distribution of groceries such as Lorenz curve, kernel density, and hot spot analysis. The results indicate reasonable distribution of groceries among the population. Several groceries are located near mosques, and this will help during disasters. Essentially, an appropriate approach to improving disaster preparedness considers groceries as points of food distribution in emergency situations, especially if they are modified to include proper storage capacity. Such an approach needs to consider both the location and the elevation, as some groceries are at low elevation, while some are near valleys. The results obtained in this research have implications for distribution of food during disaster and highlighted possible strategic planning for optimal distribution of groceries. The study suggests locating more groceries closer to residential areas rather than depending entirely on large food storage facilities that are in few locations. Our study has a high applicability as it can contribute formulation of policies and regulations for enhancing disaster management and response regarding addressing food supply in the first days following a disaster. This will help all agencies involved in moving from protection mode of practice to prevention, as recommended by Sendai Framework. The method of obtaining feedback from various stakeholders (customers, grocery tenants) complemented with GIS analysis could be adapted anywhere around the globe.

The research is limited by the non-availability of socioeconomic data on income, gender, and age groups at higher resolution (block level). The following recommendations may help in improving groceries and conducting further studies:

- Policies and regulations for building groceries: Public disaster management authorities need to be involved in policies related to groceries (e.g. disaster-proofing buildings). Authorities' involvement will help account for disaster needs in the grocery retail market. Groceries' size must be increased to 50 square meters with similar storage area to cater for disaster/pandemic food needs (long-term storage: months instead of weeks). Policies may include installation of solar energy systems and standby power generators in groceries.

- Signing PPP memorandum of agreements with the groceries to ensure they have an accepted level of responsibility and accountability to deliver certain services during disasters (quality and quantity). For example, Japan's Cabinet Office emphasizes the importance of stockpiling at least 3 days' worth of food and drink supplies (Hitomu et al., 2020).
- Providing incentives to private sector/groceries (e.g. subsidies, training, public credits, recognition, and tax reductions) for their contribution to disaster management.
- Conduct further study related to social, theoretical, managerial, and policy implications related to PPP.
- Assessing issues related to the type of PPP for disaster/pandemic management such as that based on contracts, cooperation agreements, mutual aid agreements, coordination agreements, memoranda of understanding, operational agreements, and supply agreements.
- Public awareness: implementation of health protocols for groceries, training, and organization of workshops for the staff.
- Development of near-real time system that can provide estimates of quantities of food in groceries and the number of people it can serve during a disaster. This application can also display the locations of the groceries together with their addresses, services they provide, and up-to-date food quantity.
- Assessment of building structure and age of groceries using remote-sensing technique and machine learning. Groceries could be constructed in areas with low occurrence of natural disaster, with strong structures and easy road access. Renovation and retrofit programs could be implemented to improve existing groceries' structure (redevelopment plan). Availability of existing groceries will significantly help in reducing cost and supporting disaster needs.

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Authors' contributions

Yagoub developed the research idea, wrote the paper, and managed overall project flow. AlSumaiti reviewed the paper, Alhosani distributed and collected data and edited the paper. Elmubarak edited the research proposal. Kortbi conducted the statistical analysis. Tesfaldet reviewed literature. Al Namani and Aldhanhani keyed the survey in Google Forms and managed the survey. All authors have read and agreed to the published version of the manuscript.

Institutional review board statement

Ethical approval for the questionnaire was obtained from the UAE University-Research Office on 24 August, 2022 (Application number: ERSC_2022_950).

Informed consent statement

An online informed consent was obtained from all respondents involved in the study (Appendix A).

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ORCID

M. M. Yagoub http://orcid.org/0000-0002-1718-813X

Data availability statement

The data used in this study is available from the corresponding author upon request.

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Appendix A. Questionnaire about groceries

Research Title: Role of Groceries in Disaster/Pandemic Management: Geographic Information System Application.
Fund No.: 12H013
Type of Grant: UPAR

Dear Grocery customer
Greetings

Your participation in the study about groceries is highly appreciated. Please complete the few-minutes questions below. All information will be confidential and used in summary form for research purposes only. You can withdraw from the questionnaire at any time. This study focuses on small grocery shops in neighborhoods.

Consent

I have read the above information and I voluntarily agree to participate in this study.
Please note this is an online survey. Please click on:

a. 'Enter the Survey' if you agree or
b. 'Exit the Survey' if you disagree.

Questions

Accessibility, size, and condition of structure of groceries

1. How long it takes from you to walk to the nearest grocery to your home?
   a) Less than 5 minutes b) 5–10 minutes c) 10-15 minutes d) More than 15 minutes
2. Normally, when you need items from the grocery, you?
   a) Walk b) Drive c) Order a delivery
3. Please rate the condition of the grocery building/structure near your home?
   a) Very good b) Good c) Bad d) Very bad

Food needed by residents

4. Which of the following non-perishable food you think are highly consumed in your home?
   a) Rice b) Lentils c) Flour d) Dry grains and beans
5. Which of the following canned food you think are highly consumed in your home?

a) Chicken b) Tuna c) Milk d) Beans

6. What is the average amount of rice you need every week in your home?
   a) Less than 5 kg b) between 5 and 15 kg c) 15-20 kg d) More than 20 kg
7. What is the average amount of canned food you need every week in your home?
   a) Less than 5 kg b) between 5 and 15 kg c) 15-20 kg d) More than 20 kg

Role of groceries during COVID-19

8. To what extent do you agree with the statement 'my purchase from groceries increased during COVID-19'?
   1 = strongly disagree, 2 = disagree, 3 = Neutral 4 = agree 5 = strongly agree
9. To what extent do you agree with the statement 'groceries staff apply health/hygienic protocols during COVID-19 e.g. wearing masks, maintaining social distance, cleaning the groceries'
   1 = strongly disagree, 2 = disagree, 3 = Neutral 4 = agree 5 = strongly agree
10. To what extent do you agree with the statement 'staff at groceries must have certificate or short course in health/hygienic protocols'
    1 = strongly disagree, 2 = disagree, 3 = Neutral 4 = agree 5 = strongly agree
11. To what extent do you agree with the statement 'groceries can play an important role during natural disaster or pandemic'
    1 = strongly disagree, 2 = disagree, 3 = Neutral 4 = agree 5 = strongly agree
12. Which of the following items you mostly purchased from groceries during COVID-19?
    a) Rice b) Lentils c) Flour d) Dry grains and beans
13. What is the best method for you to communicate with grocery?
    a) Telephone b) Online Apps c) Both a and b
14. Generally, in case of COVID-19 or natural disaster, you prefer to buy your daily needs from?
    b) Grocery b) Mall c) Supermarket
15. Please check the items that you need during COVID-19 but are not available in groceries
    a) Fresh meat/chicken b) Frozen foods c) Water d) Fruits/Vegetables
16. Overall, what is your satisfaction with the groceries' performance during COVID-19?
    a) Very satisfied b) Satisfied c) Neutral d) Not satisfied
17. Please feel free to write any suggestion that can improve groceries

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Demography

18. Your gender: a) Male b) Female
19. Education level: a) School b) University c) Graduate (Master or PhD)
20. Marital status: a) Married b) Single
21. Occupation: a) Employed b) Unemployed
22. Age a) Less than 18 year b) between 18 and 25 year c) More than 25 year
23. Average income of your family: a) Low b) Medium c) High
    Low: Income below AED 10,000 per month
    Medium: Income between AED 10,000 to 20,000 per month

x. High: Income greater than AED 20,000 per month